Surf Zone Mapping and Sensor System

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LONG-TERM GOALS

The long-term goals of this ONR Small Business Innovation Research (SBIR) Program Phase II effort are to develop a Surf Zone (SZ) bottom drifter measurement system that is relatively invulnerable to effects of breaking waves and that utilizes near bottom currents to provide drifter locomotion without using its own power as well as to transition the technology to support nearshore research, including model validations, and SZ naval operations. Several drifters deployed in a SZ would form a mobile SZ measurement and mapping system. Developing a riverine drifter variant had been proposed as an option. Near the end of FY06, there appears to be increasing naval interest in the riverine variant and decreasing naval interest in the SZ variant.

OBJECTIVES

Objectives are: (1) harnessing SZ currents (e.g., undertow and rip currents) to move drifters throughout and generally offshore of the SZ where they will return to the surface for data relay and optional reuse; (2) measuring key data such as bathymetry, waves, and surf; and (3) tracking drifter locations so that these data can be gridded for research and operational applications. Based on recent naval feedback, a related objective is to develop a riverine variant that would measure currents, bathymetry, and other data as it is transported along a river bed.

APPROACH

The approach is to design a barely negatively buoyant spherical drifter that is large enough (e.g., volleyball to basketball size) to accommodate sensors, a tracking system, and a system control and data analysis microprocessor as it rolls over the bottom due to currents. For the SZ variant, the concept employs new micro Inertial Measurement Units (IMU's) for inertial tracking with acoustic tracking updates considering SZ acoustic limitations. Drifters will be deployed manually beyond the swash zone and will surface outside of the SZ where data will be relayed by radio or satellite. The riverine variant will not employ acoustic tracking and will surface periodically for GPS position updates. The riverine variant is easier to develop and much lower-cost than the SZ variant.

WORK COMPLETED

Under an earlier Phase I effort, techniques were developed to track drifters using new micro IMU's with acoustic tracking updates considering SZ acoustic limitations such as noise and bubble attenuation. A preliminary design that considered size, weight and power limitations was developed.

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Preliminary data analysis methods to provide SZ bathymetry and wave information were programmed and tested with simulated drifter tracks using bathymetry from the Field Research Facility (FRF), Duck, NC. Figures 1 and 2 show external and cut-away views of the Phase I concept. Colors are used to allow distinguishing components (e.g., the inner and outer hemispheres). The inner sphere is gimbaled loosely within the outer sphere to maintain the acoustic tracking hydrophone roughly upright as the barely negatively buoyant drifter rolls on the bottom. Simplified prototype drifters without tracking instrumentation, environmental sensors, and data relay capabilities were built. One was used successfully in the field at Eglin Air Force Base, FL.

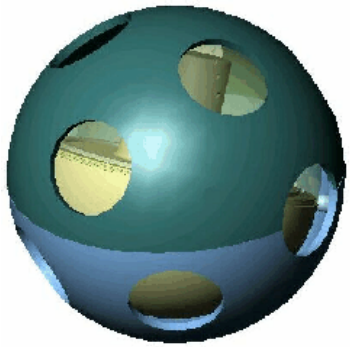

Figure 1. External View of SZ Drifter.

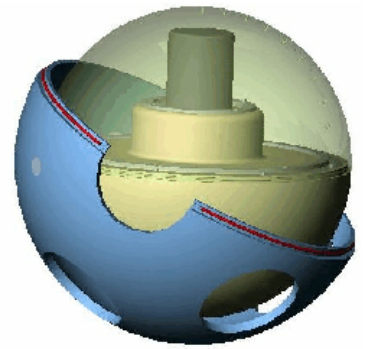

Figure 2. Cut-Away View of SZ Drifter.

The present Phase II effort started in August, 2005, but work was delayed due to our facility being flooded by Hurricane Katrina's storm surge. Three main parts of the development were completed.

First, the final mechanical design of the SZ variant (suitable for manufacturing) was finished. Final design concepts are similar to earlier concepts. Improvements allow data to be retrieved from the drifter and changing of the nitrogen cartridge that inflates a bladder to bring the drifter to the surface without opening the watertight inner lower hemisphere. The acoustic tracking system was purchased to assure that its hydrophone could be integrated. Final electronic design started and will be completed in early FY07. Figure 3 shows the open inner hemisphere of the final design SZ variant.

Second, the initial version of the SZ variant's data acquisition software was written in C language and tested with simulated sensor inputs on an Onset Computer Tattletale Model 8 microprocessor. A lower-cost and lower-power microprocessor could be used eventually. The software acquires and stores data from the IMU, the periodically operated acoustic tracking system, a pressure sensor (used for bathymetry and wave data), and a thermistor for measuring temperature.

Third, design concepts and a preliminary mechanical design were developed for the riverine variant. This variant will be constructed as a single sphere. A variable displacement system will be used so that the drifter can repeatedly surface and descend. This system will consist of a micro-hydraulic pump with a coupled electric motor, directional control valve, and ten small hydraulic cylinders. The cylinder rods are fixed to the sphere, and the cylinder tubes are allowed to move up and down through the instrument base plate when hydraulic pressure is applied. Calculations show that buoyancy changes are sufficient. GPS positions will be obtained when the drifter is at the surface. Without the acoustic tracking system, more room will be available for batteries and sensors. Additional batteries

are needed compared to the SZ variant to allow for many ascents and descents through the water column. As this variant will be used without personnel nearby after deployment, a two-way Iridium satellite data link will be provided. Experiments with the upper hemisphere hole positions and sizes will be performed to obtain a design that flushes sediment and debris. Figure 4 is a cut-away view of the preliminary design riverine variant. Figure 5 shows the riverine variant when it is submerged. Figure 6 shows the riverine variant when it is surfaced.

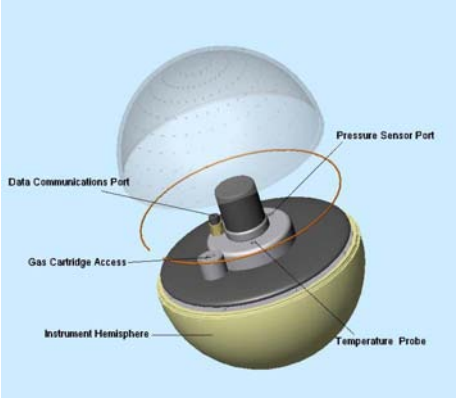

Figure 3. Open Inner Hemisphere of Final Design SZ Variant.

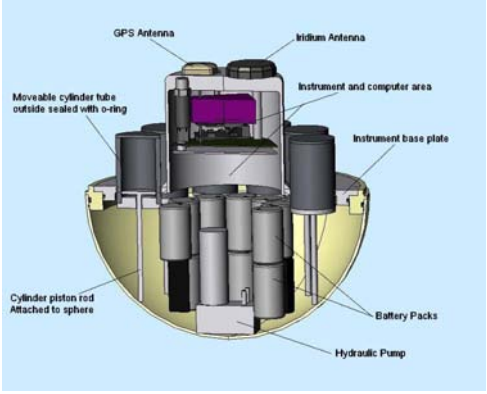

Figure 4. Cut-Away View of Preliminary Design Riverine Variant.

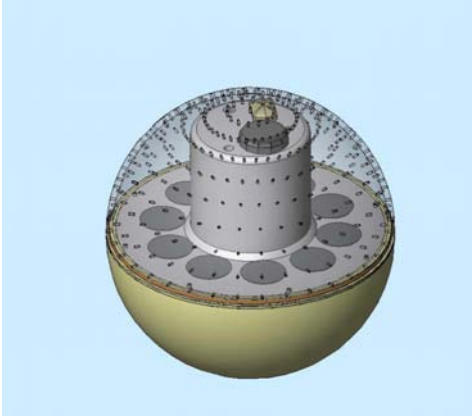

Figure 5. Riverine Variant when Submerged.

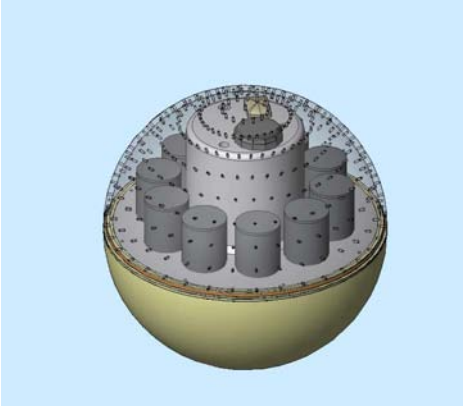

Figure 6. Riverine Variant when Surfaced.

RESULTS

During Phase I, development of the preliminary design proved that the system is feasible from mechanical and electronic engineering perspectives. Use of preliminary data analysis methods with simulated drifter tracks and FRF SZ bathymetry data showed that wave and bathymetry information in pressure data could be separated (via Fast Fourier Transform filtering) to provide non-directional wave spectra and derived wave parameters as well as bathymetry data along drifter tracks. Gridding

methods were tested showing that gridded bathymetry needed for many applications can be extracted from track data. Preliminary analysis of spatial sampling variability effects on SZ bathymetry estimation indicated that suitable data can be obtained. Limited field tests at a barred beach during low wave conditions with a simplified drifter confirmed that it rolls over the bottom due to longshore currents and undertow with undertow moving it offshore. The inner sphere moved reasonably independently of the outer sphere and remained approximately upright most of the time while the outer sphere rotated during transport by near-bottom currents. Figures 7 and 8 show deploying the drifter and recovering it by kayak after it surfaced beyond the SZ.

Figure 7. Deploying the Drifter.

Figure 8. Recovering the Drifter.

During Phase II (FY06), main accomplishments were completing the SZ variant final mechanical design, writing its data acquisition software, and developing the riverine variant preliminary design as summarized under Work Completed. During FY07 (subject to funding), the following work is planned: complete SZ variant electronic design, build and field test "operational" SZ variants, complete riverine variant final mechanical and electronic designs, and build and field test "operational" riverine variants.

IMPACT/APPLICATIONS

The importance of Very Shallow Water (VSW) and the Surf Zone (SZ), VSW/SZ, for naval littoral operations is well-known. Ocean dynamic conditions (e.g., waves, surf, longshore currents, rip currents, and undertow) and bathymetry may vary significantly in space and time. Bathymetry is important as a key input to numerical models used to determine dynamic conditions. Bathymetry uncertainties are a modeling error source that could be minimized. The technology will also support nearshore processes research in general. Emphasis is being placed on the system being portable and easily operated so that SZ data can be collected when and where it is needed rather than only at the few locations where nearshore processes experiments usually are conducted. Because the system will be able to measure near bottom properties, including currents, it could be useful for sediment transport studies. ONR suggested that a drifter's drag might be adjusted so that its path would be similar to drifting of near bottom biota. An application of major public interest would be rip current studies and development of better rip current predictions. Each year rip currents cause over 100 drownings and account for about 80% of all beach water rescues nationally.

There is increasing naval interest in real-time measurement of coastal riverine and estuary bathymetry, currents, water levels, temperatures, water physical properties and other characteristics. In these

environments, especially denied areas, personnel would only be used to deploy drifters that would scuttle after needed data are collected and relayed. The riverine variant will address these applications. There are also hydrology applications for being able to monitor conditions along rivers.

TRANSITIONS

Initial transitions would be use of the SZ variant to: (1) support naval littoral VSW/SZ operations, and (2) assist in ONR sponsored field research toward better understanding of SZ processes. Field research results also would support naval operations. An example is validating SZ numerical models that could be used operationally. Initial transitions would be use of the riverine variant by Naval Special Warfare (NSW) Groups, NSW Environmental Reconnaissance Teams (ERT's), and SEAL Teams. Potential sponsors and users include: the Commander, Naval Meteorological and Oceanographic Command (CNMOC), the U.S. Naval Oceanographic Office (NAVO), components of the Naval Sea Systems Command (NAVSEA) such as the Coastal Systems Station (CSS), NSW Groups, ONR, and the U.S. Army Corps of Engineers (USACE).

RELATED PROJECTS

SZ research performed at the Scripps Institution of Oceanography (Professor Robert Guza), the Naval Research Laboratory – Stennis Space Center [Dr. Todd Holland, Dr. Nathaniel Plant (now at ONR), and Dr. William Schmidt], and the Woods Hole Oceanographic Institution (Dr. Steve Elgar) is related. A near-surface GPS-tracked SZ drifter was developed by a Scripps / Woods Hole team (Schmidt et al., 2003). Dr. Holland's group is involved in extracting data from SZ video data. Phase II field tests may be at Eglin Air Force Base, FL, where they have installed instrumentation. Dr. Plant performed recent research enabling analysis of spatial sampling variability effects on estimation of SZ bathymetry data (e.g., Plant et al., 2002). Collaboration will also be sought to participate in future field experiments at the FRF, Duck, NC.

There have been many uses of surface and bottom drifters in rivers although in most cases the drifters were not instrumented and were used simply as Lagrangian drifters to infer currents. Development of the real-time profiling riverine variant is apparently a new concept with little related work.

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